JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOL. 29 MAY 15, 1939 No. 5

GEOPHYSICS.—*From the center of the earth to the sun.*[1] N. H. HECK, U. S. Coast and Geodetic Survey.

It is customary for the retiring president to select a subject related to his work. When that work deals with the broad phases of both terrestrial magnetism and seismology, the logical procedure is to present a broad review rather than the results of his individual endeavor.

The theme "From the Center of the Earth to the Sun" might be construed as dealing with the whole field of science, but the subject of the present paper is narrowly restricted to what can be learned from observations in seismology and terrestrial magnetism about the interior of the earth, its atmosphere, and the sun. While the principal findings have all been announced, appraisal of their validity is needed in some cases. An opportunity is also afforded to discuss errors of observation as related to the recently developed need for higher accuracy.

Since the work in both subjects is highly cooperative, the historical background, especially in the United States, must be understood. In the case of terrestrial magnetism, the Coast and Geodetic Survey (hereinafter referred to as the Coast Survey) has been making observations for more than 100 years, and for nearly 40 years there has been an effective program, including the magnetic survey, the repeat program at 5- to 10-year intervals, and the operation of five widely separated magnetic observatories. Its great contribution has been in putting this information into convenient form for use by investigators.

Much of the interpretation of this and of other data from all over the earth has been done by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington (hereinafter referred to as the Carnegie Institution), whose main purpose is the investigation of the subject of terrestrial magnetism in relation to other phenomena and for the earth as a whole. It is well known that its program has included observations in a number of lands where no magnetic sur-

[1] Address of the retiring president of the Philosophical Society of Washington, delivered January 14, 1939. Received March 27, 1939.

vey exists, the operation of two well-equipped observatories in foreign countries, and, for many years, magnetic observations at sea.

For the earth as a whole many nations engage in both magnetic observation and interpretation of the results. Among these Great Britain, Germany, and some of the other nations of northwestern Europe have been outstanding. There are in all about 80 magnetic observatories.

The situation in seismology is evidenced by the existence of more than 400 stations for recording earthquakes scattered over the earth, but the majority of them and most of the interpretative work have been in Europe and Japan. Only recently has the United States begun to take an outstanding place. Contributions to knowledge of the interior of the earth have come from organized groups in California, the Mississippi Valley, Washington, D.C., and New England. The Coast Survey has been engaged in direct and cooperative operation of observatories, interpretation of their records, location of the places of origin of earthquakes, and in the measurement of strong earth motions.

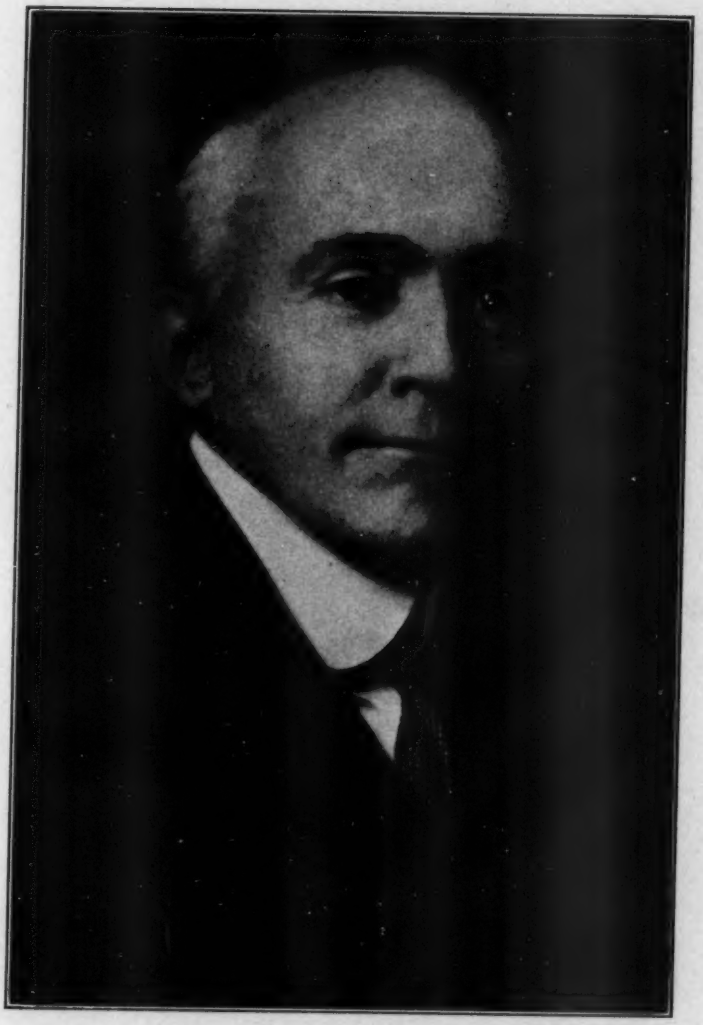
Since the earth sciences necessarily deal with the earth as a whole, generalization from limited observational data is necessary. In the case of both terrestrial magnetism and seismology, the necessity of having continuous observations of high accuracy, aside from all questions of cost, places a definite limitation on the number and spacing of the places of observation. It is most important that observations be sufficiently accurate to meet all present and future requirements.

ERRORS IN OBSERVATION

Errors in observation will lead to erroneous conclusions, and the use of statistical methods cannot remedy basic defects. Complete discussion would be too long, and consideration of time in seismology and of absolute measurements in terrestrial magnetism will have to serve to bring out the essential points.

Errors of Time in Seismological Records

In seismology time is related: to earthquake location, both in position and depth; to the physical characteristics of the earth's interior; and to the verification and location of surfaces of discontinuity. The source of this information is the travel time curve, in which the time of wave transmission from place of origin of earthquake to recording station is plotted against distance, or the equivalent table. The effect



NICHOLAS H. HECK
President, Philosophical Society of Washington
1938

of a given error in time varies in different parts of the curves and tables and may be very large.

The needed accuracy of time as scaled from the records (0.1 or 1.0 second, as earthquakes are near or distant) may seem readily obtainable, but accuracy attained without difficulty under favorable conditions may be almost unattainable, or incapable of being maintained, at remote stations, because of mechanical and electrical difficulties.

The requirements are that a drum be turned at a uniform rate by synchronous motor or by clockwork preferably controlled by a suitable governor; time marks must be placed at uniform intervals; and the time must be absolute. Electric current with accurate frequency control is by no means universal, time-marking chronometers have varying rates, and the frequent United States Naval Observatory time signals, indispensable as they are to seismologists, cannot in themselves provide continuous absolute time. The use of a radio signal to mark the same instant on all the records of a network of stations suggests the recording of continuous time signals, but it has not been found practicable to use the second-by-second signals of the Dominion Observatory, Ottawa, Canada, or the frequency control signals of the National Bureau of Standards for this purpose. Even if suitable minute-by-minute signals were available, provision would have to be made for failure of radio reception.

In addition to the control errors, there is also the error in selecting the exact time of beginning of an activity, a problem common to both seismological and magnetic records. The identification of the beginning of an earthquake phase or of a sudden commencement of a magnetic storm depends in a large measure on the sharpness of the arrival, that is, the slope (Fig. 1). Very sharp arrivals can be determined with great accuracy, but emergences with flat slopes or complex arrivals are not easy to measure precisely. In the case of earthquakes the presence of microseisms may make phase identification difficult. Seismological stations have been appraised as having inaccurate time control when the errors in interpretation were due to microseisms.

An open time scale is helpful, but it is a fallacy to assume that the more open the scale the greater necessarily the accuracy. With too great increase the steep slopes may become relatively flat. The quick run magnetic recorder of La Cour with a speed of 180 mm per hour as against the 15 or 20 mm per hour in customary use makes it possible to determine the time of certain arrivals with great accuracy, but the records as a whole are difficult to interpret and cannot be

satisfactorily used in filling gaps in records with the ordinary time scale.

Each individual seismological record is complete in itself as a source of seismological data, its limitations depending solely on the quality of the installation and the standards of operation.

Errors in Conversion from Relative to Absolute Magnetic Values

In the case of terrestrial magnetism, the errors to be discussed are those related to the conversion from relative to absolute values. Since

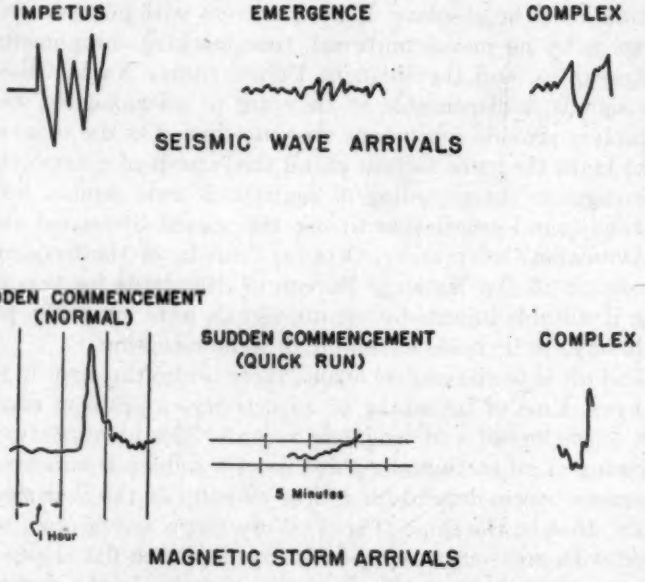


Fig. 1.—Records of seismic wave arrivals and of magnetic storm arrivals.

no means has been found to make continuous absolute observations of the magnetic elements, the continuous records are relative and can afford absolute values only through absolute determinations at suitable intervals. Certain investigations in terrestrial magnetism appear to require only relative values, but full reliance cannot be placed on their accuracy without control by absolute observations.

The relative values themselves have their own sources of error, especially instrumental imperfections and uncertainty in the elimination of temperature effects (in the case of intensity). There is some attempt at temperature and humidity control at most observatories,

but at remote places laboratory conditions cannot be reproduced. There are similar errors in the absolute determinations, and there are other sources of error. In the Gauss method of measuring horizontal intensity, which is still in general use in spite of the adoption of electrical apparatus at a limited number of observatories, the observations require considerable time, during which the element may change in an irregular manner. Horizontal intensity requires two distinct observations (oscillations and deflections), and vertical intensity depends on the further measurement of dip. Each has its own source of error. Furthermore, only one element can be measured at any given point at the same instant.

The assignment of correct absolute values to the baseline (straight

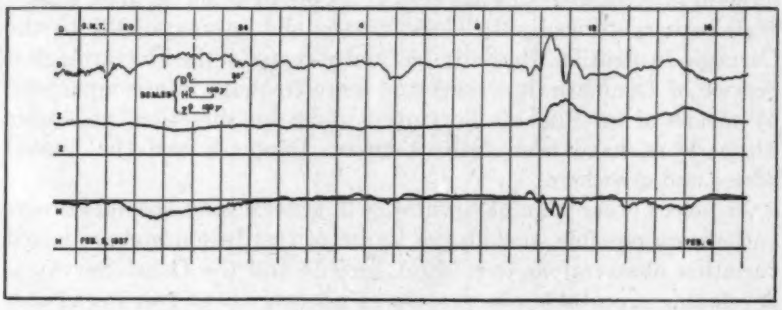


Fig. 2.—Record of magnetic variation. Abscissae represent time in hours; ordinates represent D, H, and Z, with scales as indicated.

line of reference on the magnetogram, Fig. 2) is affected not only by the errors of observation but by the comparative infrequency of absolute determinations at most observatories. At Abinger, England, several determinations are made each day, but such procedure is rarely feasible. There is always the possibility of a sudden change in the position of the variometer magnet due to some mechanical change, which affects the proper assignment of baseline values. Temperature compensation is not always perfect.

In a different class of error the magnets may not be in the plane in which they should operate, in which case they measure the change in the resultant of two elements rather than of a single element. Recent examination with more refined methods shows that many instruments had magnetic parts near the magnet. Good progress is being made in eliminating these sources of error.

Though the list of possible errors sounds formidable, in practice the results are good. However, the degree of accuracy attempted—0.1

minute in declination and dip and 1 gamma (10^{-5} gauss) in intensity —is consistently obtained at few observatories, and there are cases of gross error. Eternal vigilance is the price of accuracy.

Standardization

Even if precise data were available from every observatory, errors sufficient to affect adopted theories might arise from differences in standards. The Carnegie Institution has adopted an international standard, which is now maintained at Cheltenham jointly with the Coast Survey and the National Bureau of Standards. The use of the sine galvanometer of the Carnegie Institution at Cheltenham to determine horizontal intensity has enhanced the value of the results. A series of intercomparisons has been going on for years between United States observatories by the Coast Survey and internationally by the Carnegie Institution. Recently La Cour, director of the Meteorological Service of Denmark, has suggested more frequent intercomparisons by means of instruments developed under his direction, and some comparisons have been made between Denmark and the United States and elsewhere.

At places other than observatories in general only absolute observations are possible, though the Carnegie Institution makes diurnal variation observations over short periods and the Coast Survey is developing a portable observatory to operate about two weeks at a site. In most cases correction for magnetic changes must be deduced from the records of a distant observatory. V. Vacquier, of the Gulf Research Laboratories, has shown in the case of vertical intensity that on certain days this practice will lead to erroneous results, because of local variations which may extend over a distance of 300–500 miles. Fig. 3 shows changes in vertical intensity on a given day from Cheltenham, Md., to Tucson, Ariz., magnetic observatories.

The demand for accurate determination of the magnetic elements, especially vertical intensity, has grown, since the measurement of that element has proved to be a useful method of discovering geological formations associated with oil and minerals. The anomalous situation exists that differences are more accurate than absolute values. Such detailed surveys would be more valuable if the values were absolute. The stress that has been laid on the reduction or elimination of errors may seem excessive, but it is based on a conviction that one of the important needs is steady improvement in instruments and methods by all agencies engaged in magnetic and seismological work. The Coast Survey is committed to such a program.

INTERIOR OF THE EARTH FROM SEISMOLOGY

The principal facts that are needed regarding the interior of the earth are the viscosity, density, elasticity, temperature, pressure, liquid or solid condition, gradual or sudden change of physical condition, and especially whether the earth consists of a series of concentric shells. For the deep interior the passage of earthquake waves is the principal and perhaps the only source of detailed information, though certain facts can be deduced from other sources. The trans-

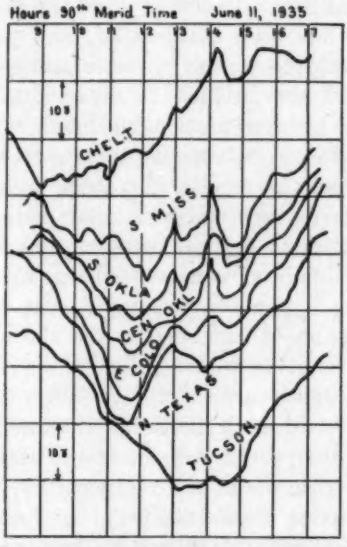


Fig. 3.—Simultaneous variations in vertical magnetic intensity.

mission of the waves follows definite laws fixed by the condition of the medium traversed, which it therefore reveals. In some cases seismology merely reduces the number of unknown factors and indicates a possible solution.

Of the desired facts listed regarding the interior of the earth, seismology gives definite evidence of change of condition, especially through the location of layers of discontinuity; gives some idea of elasticity, compressibility, density, and rigidity; tells little about temperature and pressure; and tells that the earth is solid with the possible exception of the core, whose solidity remains somewhat doubtful.

If conditions within the earth were known, travel time curves could

be computed from theory alone. The approach to the problem is quite different. Seismological stations in many parts of the earth have furnished a vast number of records of earthquakes at every possible distance from the recording station. These records give transmission times, and by means of suitable mathematical treatment and certain broad assumptions velocity can be deduced for every part of the path traversed. This makes possible the accurate location of earthquakes whether of normal depth or deep focus, and also knowledge regarding the interior of the earth, since assumptions regarding it must fit the observed times. In recent years the process of correlation and interpretation has been accelerated, and probably the major portion of the arriving phases have been identified.

There are two methods of attack. One is by studying a single earthquake, using records from all parts of the earth, which brings out differences in transmission in various regions. The other, an older method, is to average the results of a large number of determinations from earthquakes recorded at similar distances. Seismologists have used both methods in preparing various travel time tables, which are by no means in agreement with one another.

Seismology makes it possible to compute the density of the earth at different depths, that at the surface and the mean density of the earth being known in other ways. Values of special interest as given by Bullen for given depths are as follows: 42 km, 3.32; 2,800 km, 5.50; 3,000 km, 9.82; center of earth 12.17. Mean value for the earth is 5.52; for core 10.76; and for portion outside of the core, 4.49.

Seismology tells little about the temperature, though it is an important element in fixing the conditions of earthquake wave transmission. This lack of information is especially regrettable because the question whether the temperature continues to increase at the rates given by measurements in wells down to 15,000 feet is important in magnetism as well as in seismology.

Laboratory procedure is giving useful information regarding probable conditions in the earth's crust. Pressures now available (about 50,000 atmospheres) correspond to the depth of about 100 miles, but only limited application has as yet been made to seismology.

Core

One of the best-established facts in seismology is the existence of a core with its surface at a depth of 2,900 km (Fig. 4), so that its diameter is a little more than half that of the earth, and it contains one-sixth of its volume. The core is known both through the determination

of the position of its surface and because the velocities within it are very different from those outside of it. The velocity, according to Gutenberg and Richter, changes suddenly at the boundary of the core from 13.7 to 8 km per second, and within the core it increases to 11.4 km at 5,150 km depth and remains practically unchanged to the center of the earth. The question whether the core is liquid or solid is still an open one. Brunner states that he has found no absence of activity at proper places on the record for arrival of transverse waves through the core but rather too much activity and none of it outstanding. The inference is that if these waves traverse the core they carry little energy.

The question whether the core, like many meteorites, consists of iron and nickel may be of importance in connection with terrestrial magnetism. The evidence for such composition has often been given and seems quite satisfactory. Jeffreys has stated that if the pressure could be removed the density of the core would be equal to that of iron at the surface. The discontinuity at the surface of the core seems fairly sharp. Certainly there are no great irregularities in the transition.

Mantle

That part of the earth which lies between the core and the bottom of the crust is known as the mantle. It has no major discontinuity, but it seems to have several minor ones which probably indicate sudden change of physical condition in addition to the gradual change with depth, a characteristic of the mantle. Various discontinuities have been suggested, those receiving most consideration at present being at about 1,000 and 400 km (Fig. 4). It is noted that the 400 km discontinuity, if real, is of less depth than the deeper of the deep-focus earthquakes, which reach 700 km. However, the layer of discontinuity is presumed to extend around the earth, while the deeper earthquakes are confined to areas of limited extent. The general distinction between the crust and the mantle is that the conditions in the mantle are nearly the same everywhere at the same distance from the center of the earth, while the crust is quite variable. Regional anomalies in transmission of waves through the earth indicate that in some regions there are differences which may extend into the mantle.

Deep-focus earthquakes are confined to a portion of the rim of the Pacific Ocean with a few exceptions (Fig. 5). The criteria by which they are recognized are that their phases do not fit the tables for normal earthquakes with depths of 50 km while proper assumption of

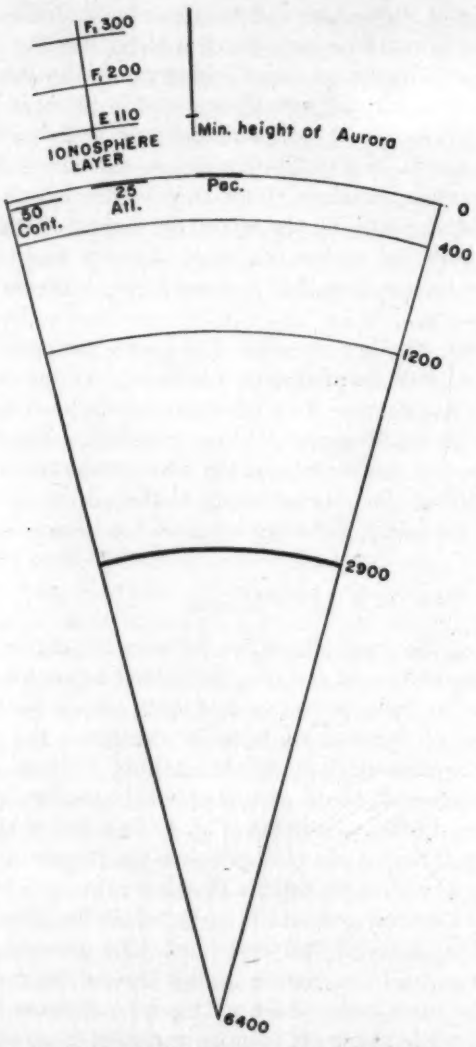


Fig. 4.—Concentric layers in earth and atmosphere.

depth gives satisfactory values; and that there is almost complete or complete lack of surface waves. They often exhibit an unexplained phenomenon: Waves which have gone from focus to surface and there been reflected arrive with more energy than the direct waves from the focus.

The deep-focus earthquake seems to conflict with the theory of isostasy as there should be no possibility of building up of stress below the depth of compensation, which at most is held to be less than 100 km. However, these earthquakes act like tectonic and not volcanic or explosive types, so that there must be gradual building up of stress. Gutenberg has pointed out that while there may be no strength at such depths there is viscosity, so that a rapidly developing stress might suddenly overcome the resistance with resultant earthquake.

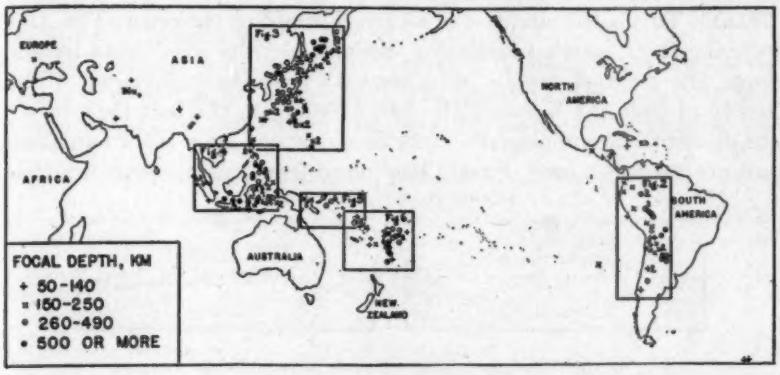


Fig. 5.—Deep-focus earthquakes. Numbers attached to symbols represent two or more shocks from nearly the same source. (Courtesy Geological Society of America.)

Crust

The crust of the earth is only a small portion of its volume, but it is of extreme importance from the human viewpoint, from the fact that its surface is the platform on which all magnetic and seismological observations are made and because it is itself infinitely more varied in structure than the rest of the earth, the variety in general increasing toward the surface. All except deep-focus earthquakes, which are a small proportion of the whole number, occur within the crust. The effects of the severe earthquakes in causing damage and aiding in the processes that bring about geological change constitute the principal reason for earthquake observations from which scientific information regarding them is obtained.

For the region immediately beneath the surface, whether on land or under the ocean bottom, information has been obtained by the use of artificial seismic methods based on explosions. Additional information has been found in regard to the surface layers on land through the measurement of strong earthquake motions and the use

of vibrating machines and highly sensitive recording apparatus. The Coast Survey has obtained important results in these two fields.

Thickness of the Crust from Isostasy

The thickness of the earth's crust is uncertain, since it can be determined only by geophysical methods, and different methods give different results. The theory of isostasy, according to the Pratt hypothesis (Fig. 6), gives a rather uniform thickness of crust except for surface variations in height, since computations give a depth a little less than 100 km. This is the simplest of all conceptions of the crust. The Airy hypothesis of isostasy calls for uniform depths over considerable areas, the greatest depths being beneath the mountain areas. A difficulty in choosing between the two arises from the fact that an accurate depth of compensation can be computed only for a mountain and not for a flat area. Byerly has found from seismic evidence that

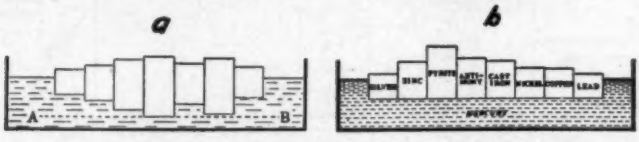


Fig. 6.—(a) Illustrates Airy or "roots of mountains" theory; (b) illustrates Pratt theory.

the Sierra Nevada in southern California have a granite root projecting perhaps 20 km below the normal depth for granite. The continental layer is deeper beneath the Alps than the rest of Europe. This might seem to give indirect evidence in favor of the Airy hypothesis. Macelwane also favors it for seismological reasons.

As to the exactness of the depth of compensation adopted, the computations permit some degree of latitude. Furthermore, while isostasy expresses the view that the crust has a strong tendency to equilibrium at a certain depth, perfect equilibrium can never be attained so long as meteorological processes, with their consequent shift of load on the earth's crust, continue.

Thickness of Crust from Seismology

The crust derived from seismology is quite different from that just described. Seismic waves give evidence of its thickness in several ways, but only one method gives quantitative results—the use of travel time curves of the several parts of the preliminary waves from earthquakes within a few hundred kilometers. This method is well established and is responsible for the determinations of Jeffreys and

Mohorovicic in Europe and of Gutenberg in California. Instruments for recording nearby earthquakes and time correct to 0.1 second are needed. These conditions are met only in a few regions.

Surface waves in spite of their complexity give some information regarding the crust. They indicate the great difference in the Pacific Ocean basin, since the surface waves traversing it have a speed nearly 20 percent higher than for the continents. They give evidence of a vertical surface of discontinuity of moderate depth around the Pacific which corresponds to the major earthquake belt. Other applications give promise.

Results from various sources are given in Table 1. They are clearly preliminary and highly generalized. The broad picture includes double or multiple continental layers aggregating 40–50 km, becoming less

TABLE 1.—THICKNESS OF CONTINENTAL LAYER
(ACCORDING TO GUTENBERG)

Locality	Continental crust (depth in kilometers)
England	20
Southern Germany	45
Eastern Alps	50
Southeastern Europe	About 45
Caucasus	About 45?
Central Asia (region of 40° N., 70° E.)	40–50
Philippine Islands	About 50?
Japan	About 50, decreasing toward the Pacific
Southern and central California	30–40

toward the borders; a total depth of 20–25 km for the non-Pacific type of ocean bottom and no similar layer at all for the Pacific. Needed detail is lacking at every point.

The complications are well illustrated by an approximately correct section of the crust in the vicinity of Japan, which, however, omits the geological details (Fig. 7). The depth of compensation is highly approximate, since it cannot be determined accurately in such a varied region with great gravity anomalies.

In regard to the coordination of the two conceptions, it must be remembered: first, that the depth of compensation is rather indefinite, with rather wide possible limits; and second, that there seems to be no reason why there should necessarily be at the depth of compensation sharp physical changes which would produce a surface of discontinuity. Besides, there appears to be no discontinuity beneath the Pacific.

It seems best for the present to accept the viewpoint that the two

conceptions cannot be completely reconciled, but neither isostasists nor seismologists should abandon hope of a more satisfactory future conclusion.

TERRESTRIAL MAGNETISM AND THE EARTH

Although terrestrial magnetism is to serve as a bridge from the earth to the atmosphere and to the sun, it is largely of the earth. The

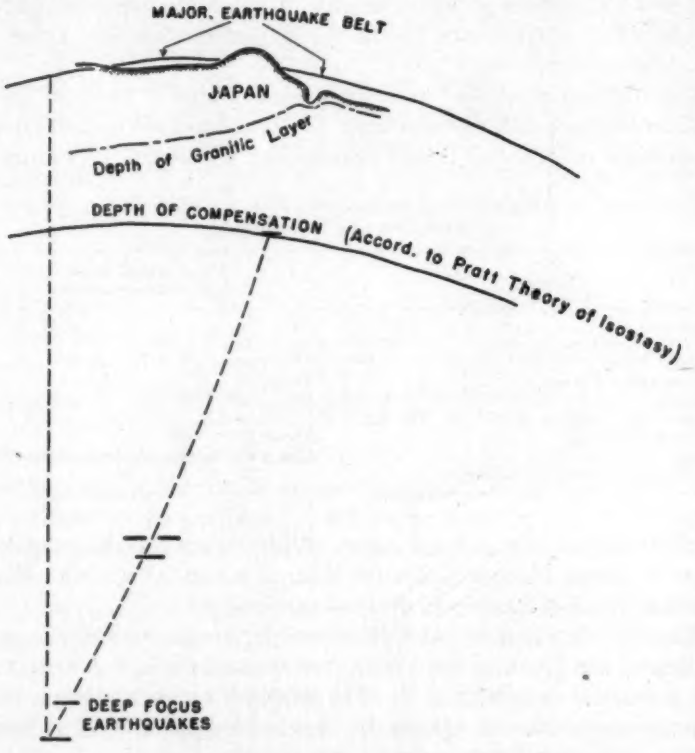

MAJOR EARTHQUAKE BELT
JAPAN
Depth of Granitic Layer
DEPTH OF COMPENSATION (Accord. to Pratt Theory of Isostasy)
DEEP FOCUS EARTHQUAKES

Fig. 7.—Section of earth's crust near Japan.

surface magnetic field resembles approximately that of a weakly but permanently magnetized sphere of the same size as the earth, but it is not so simple. Bauer has shown that about 94 percent of the earth's surface field originates within the earth. If the meaning of this were fully understood magnetism might become a competitor with seismology in giving facts about the earth's interior.

Since the magnetism is not uniformly distributed and since part of it comes from outside the earth, it is fortunate that the more or less rapid changes which add to the complexity also contribute to the solution of some of the problems.

The part of the earth's surface field that is not from within the earth is due to varying and also possibly to constant stationary current systems in the earth's atmosphere, and it is a source of information in regard to the atmosphere and the sun. The varying electrical currents flowing in the atmosphere induce currents within the earth and therefore contribute to the observed surface field of internal origin. If this part is removed from the surface field of internal origin, the remainder is called the earth's main field; its surface values are given with all the accuracy needed for most purposes by the magnetic maps used by navigators and surveyors. Its cause is unknown at present and constitutes one of the greatest of the unsolved problems of physics.

The continuous recording at magnetic observatories supplemented by measurements at selected points at 5- to 10-year intervals gives a continuous picture of the earth's surface magnetic field in its entirety. The observatories are badly distributed, with overconcentration in Europe and sparsity in other parts of the earth, especially in the Southern Hemisphere and the polar regions. The five observatories of the Coast Survey and two of the Carnegie Institution are in regions of few observatories. In the case of the polar regions, a temporary network of observatories was operated during the so-called Polar Years of 1882–83 and 1932–33, and chiefly in the north polar region.

This uneven distribution of observatories has placed a heavy burden on the repeat work of the magnetic survey. Various governments including that of the United States have done their share, but since 1905 the magnetic survey of land areas not so taken care of and of ocean areas has been carried on by the Carnegie Institution. Since the loss of its nonmagnetic ship *Carnegie* in 1929, the ocean survey has stopped, but it is expected to be resumed when the British Government's nonmagnetic ship *Research* takes up the ocean work. This is especially important since any serious lack of continuity not only detracts from present knowledge but destroys some of the value of observations made in the past at great cost. The United States should have a small nonmagnetic ship to work in waters adjacent to its coasts.

Main Field and Secular Variation

The main field and secular variation have been studied by an application of the method of spherical harmonic analysis due to Gauss and developed by others. A uniformly magnetized sphere of the same size as the earth gives a good first approximation. Its north pole

Fig. 8.—Earth poles and auroral belt.

known as the geomagnetic north pole is near Smiths Sound, Greenland, about 12° from the geographic north pole (Fig. 8). This is different from the north pole of 90° dip or north magnetic pole, located on Boothia Peninsula, north Canada. The field, at points in space, is that of a short magnet or dipole near the center of the earth, and it varies inversely as the cube of the distance from that point. This is the regular part, and the more irregular complicated part varies more

rapidly with distance and is negligible at a few hundred miles above the earth. At the surface of the ground the contribution of the irregular portion may be very large and is an important factor in the tracing of isomagnetic lines, which even in slightly disturbed areas can be drawn only approximately if the survey is not in great detail. In general, there is merely a distortion of the isomagnetic lines (Fig. 9), but in some cases there may be a local magnetic pole. In some places interpretation gives the approximate depth to the basement rock and other valuable geological information.

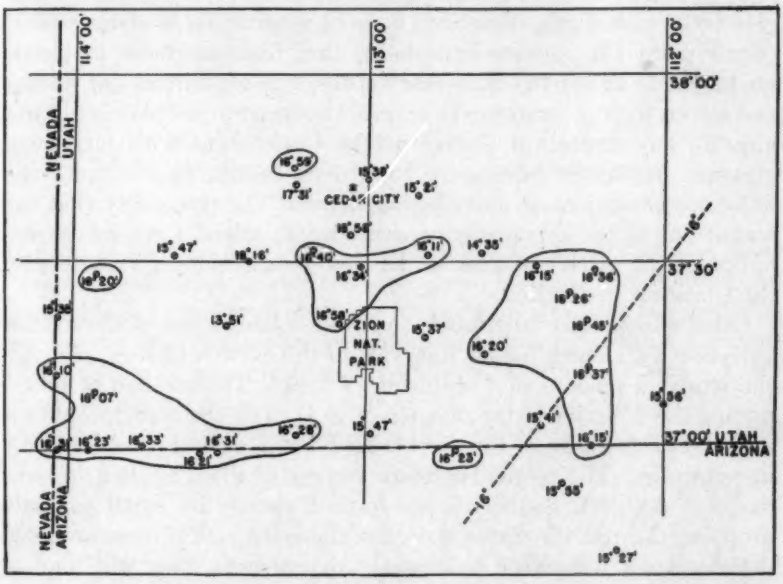


Fig. 9.—Area of disturbance in magnetic declination.

Closely allied with the problem of the origin of the main field is that of its secular variation or change with time. Measured data giving its characteristics are as yet scanty, since its more noteworthy changes with time are slow and completed only throughout the course of centuries. Our records are most complete for the magnetic declination or the departure of the compass direction from the true north. In declination, a complete cycle is defined as a return to the original position after excursions to extreme positions on either side. The duration of a cycle is, according to data available for western Europe and for the eastern United States, of the order from 300 to 500 years or

more. It would be more desirable to deal with the values of total magnetic force, thus using both intensity and direction of the field; this is possible for a period of less than 100 years, and over a much shorter period of time for the earth as a whole.

As in seismology the difficulty is in the present impossibility of direct observation of physical conditions deep within the earth. If the regular part of the earth's magnetism is ascribed to uniform magnetization throughout its volume, the required intensity of magnetization is much greater than that of the surface layers. Reasons have been given for supposing that the earth's temperature increases progressively with depth. Since iron loses its magnetism at about 800° C (Curie point), it appears improbable that ferro-magnetic materials are magnetic at any but moderate depths. The experiments of Adams and Green with pressure up to several thousand atmospheres did not indicate any important change of the Curie point with increasing pressure. However, laboratory conditions cannot approximate the unknown conditions at considerable depths. The possibility that the magnetism of the subatomic structure might afford a possible explanation of the earth's magnetism has led to extensive experiments by the Carnegie Institution.

Other efforts have been made to obtain a knowledge of the secular variation over much longer intervals in the earth's history, through the study of igneous and sedimentary rocks. The method of determining the direction of the magnetism in lava on the assumption that it took the direction of the earth's field while cooling involves many uncertainties. The method is more successful when applied to sedimentary deposits. Sediments are formed usually by small particles dropping through the water of oceans and lakes, and if these are magnetic and not influenced too greatly by currents, they will tend to align themselves in the direction fixed by the earth's field at the time. Piggott's cores of the ocean bottom and carefully selected lake varves have given McNish and Johnson, of the Carnegie Institution, an opportunity to investigate this possibility. The preliminary results indicate that the method has great possibilities, especially since in the case of lake varves the time can be identified over many thousand years.

The continuous record of secular change at the observatories of the Coast Survey (Fig. 10) show fluctuations from year to year which are real. These fluctuations would undoubtedly be useful in determining the nature of secular change if they could be correlated with other phenomena.

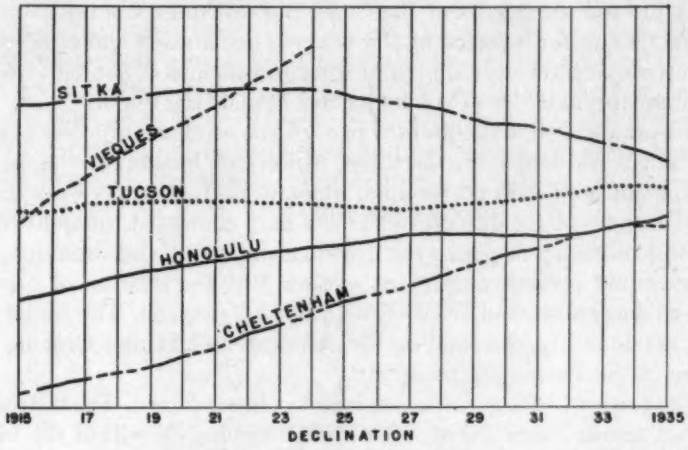


Fig. 10.—Secular variation at United States observatories.

Isopors

Fisk, of the Carnegie Institution, was the first to plot isopors (lines of equal annual change) for the earth as a whole and to prepare world maps. He did this for all elements for the year 1925, the isopors being necessarily approximate because of limited data. He found a considerable number of isoporic foci or regions of maximum change. Later observations were made in South Africa, and the change in the position of the foci between 1927 and 1937 is shown (Fig. 11). In 1936

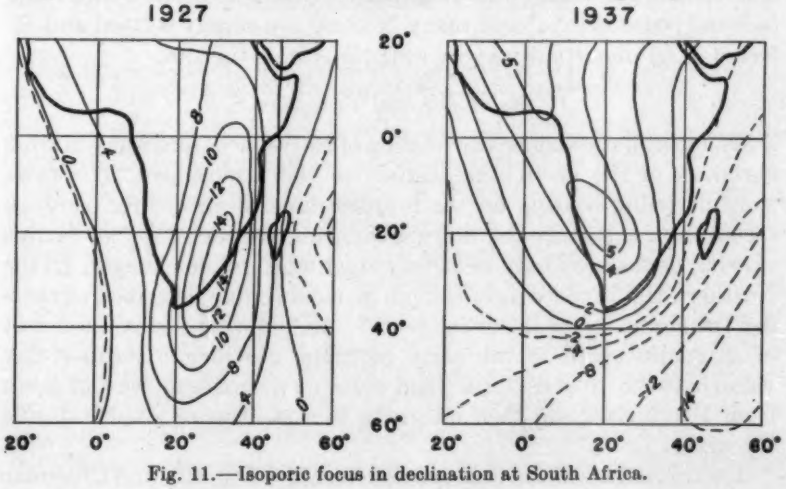


Fig. 11.—Isoporic focus in declination at South Africa.

Heck plotted the results of the Coast Survey and cooperators in the United States for a period of 155 years in declination and of 80 years in horizontal intensity. He found some indications of the movements of minor foci and also of the major foci outside the region.

It is evident that the greater part of the secular variation is local and not world-wide. Furthermore, centers of maximum change are permanent neither in position nor amount, and they may even disappear. Isopors of the different elements may change at different rates. If total-intensity isopors were drawn in intensity and direction, the maps would present a different picture, but the relation of isoporic foci to continents and oceans would not be changed. The important foci are found in the land or the Atlantic and Indian Oceans, and those in the Pacific are moderate.

The cause of secular variation is as yet unexplained. The indication is that marked changes of some kind are going on within the earth, but the nature of these changes is still a matter for speculation.

TERRESTRIAL MAGNETISM AND THE ATMOSPHERE

We next consider the relations between terrestrial magnetism and the atmosphere. Even though there are extensive data, many of these relationships are complex and difficult to understand. The interrelated elements of the problem include: the atmosphere with its varying complex conditions; radio transmission and the ionosphere; current-systems in the upper atmosphere; aurora; magnetic storms of normal or bay form; pulsations; disturbances associated with radio fade-out; cosmic rays; and many of these are closely related and affected in an important way by radiations from the sun.

Solar Diurnal Variation

We must first consider the relation of the solar or quiet-day diurnal variation of the earth's magnetism to the atmosphere. The most fruitful results bearing on the problem have been secured through the study of this quiet-day diurnal variation. On such days the earth's varying field shows only relatively small and simple changes. In the Northern Hemisphere its effect can be most simply described as causing the compass needle to follow the sun, pointing a maximum east of magnetic north in the early morning, reaching a mean-of-day value between 10 and 11 A.M., and pointing a maximum west of north from 1 to 2 P.M., and then returning to a mean-of-day value during the night.

The diurnal variation changes with locality (Fig. 12), and Chapman

has found from magnetic observatory data that, whatever the cause, a simple current-system (Fig. 13) will account for the mean daily variation and its geographical distribution over the earth. The system remains fixed with regard to the line earth-sun, and the earth rotates beneath it. In both Northern and Southern Hemispheres there are two sunlit current circulations and two considerably weaker circulations mainly in darkness. A total of 10,000 amperes flows between successive current lines. This current-system corresponds to the an-

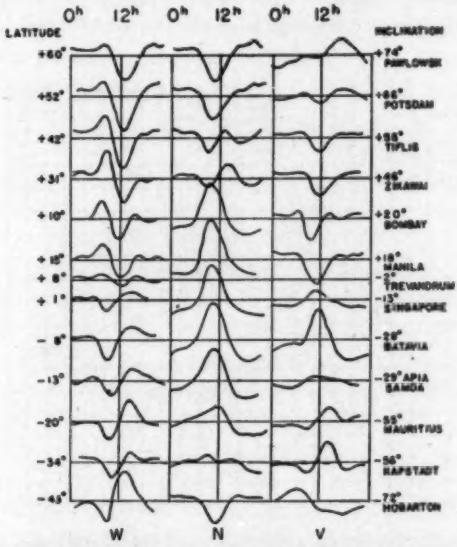


Fig. 12.—Daily variation of terrestrial magnetic elements at equinox. The inclination gives the magnetic latitude. (After Angenheister.)

nual average of the quiet-day diurnal variation; it therefore only approximately represents conditions on individual days.

The probable height and cause of this current-system cannot be uniquely inferred solely from considerations of terrestrial magnetism. However, further nonmagnetic considerations such as the existence of the ionosphere and ultraviolet radiation from the sun may afford a solution. The ionosphere is an electrically conducting portion of the upper atmosphere with regions of maximum ionization at approximately 110 km, 200 km, and 300 km above the earth and known as the E, F_1, and F_2 regions (Fig. 4). These serve to reflect radio waves and presumably to conduct electrical currents responsible for the variations of terrestrial magnetism. Such ionization is due, at least

in part, to solar radiations in the far ultraviolet which fail to penetrate to the earth's surface.

A current-system flowing in the earth's atmosphere is likely do so in one of the known ionized regions. A dynamo theory was first suggested by Balfour Stewart and later developed quantitatively by Schuster and Chapman. According to this theory the electric currents are generated by the horizontal motion of ionized air across the lines of force of the earth's permanent magnetic field. The horizontal component of this motion is produced by atmospheric oscillations due to thermal expansion and tidal effects reinforced in part by reso-

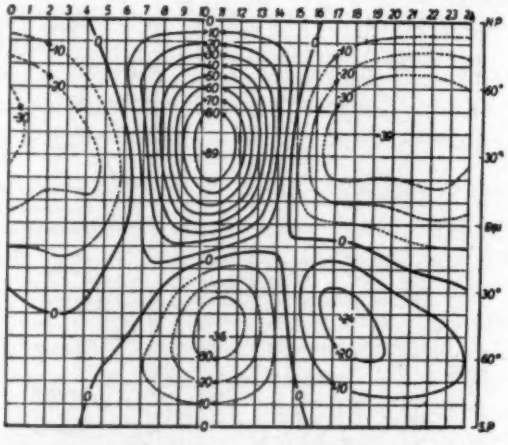


Fig. 13.—Atmospheric systems of electric currents which could produce the solar daily magnetic variation. (After Chapman.)

nance. Other theories advanced include the drift current theory of Chapman and the diamagnetic theory of Gunn, operative in the long free path region of the ionosphere. Since the electrical conductivity of the atmosphere as given by the quiet-day diurnal variation is much greater than that given by radio echo observations, Appleton believes that conditions are such that the radio reflections do not measure all the ionization.

The solar-flare disturbance, the only definite manifestation of a connection between magnetic changes on the earth and visible manifestations on the sun, gives direct indication of the location of the current-system producing solar diurnal variation. Observations and studies have been made at the National Bureau of Standards and the

Carnegie Institution. At Huancayo all phenomena, solar flare, radio fade-out, and magnetic disturbance, were observed simultaneously on one occasion, giving proof if any were needed that the phenomena are simultaneous. The most striking feature is the radio fade-out, which may last from 15 minutes to 1 hour. It is established that the solar flare is accompanied by an increase of ultraviolet ray emission by the sun, causing increased ionization just below the E layer of the ionosphere. McNish showed that the chief effect is a marked increase in the intensity of the current-system responsible for the quiet-day diurnal variation. This favors the view that the current-system is caused by dynamo action and flows below or at the base of the E region of the atmosphere.

Lunar Diurnal Variation

The lunar diurnal variation is associated with the motion of the moon about the earth. It shows some similarities in general type to the solar variation, but differs in an important respect since it depends on lunar time. Only the dynamo theory is applicable to the lunar diurnal variation. Its amplitude is only one-fifteenth of the solar diurnal variation, although the tidal effect of the moon is twice as great as that of the sun. The explanation is that while the tidal action of the moon is the primary cause of lunar diurnal variation, the moon has no effect in producing ionization. As in the case of the quiet-day solar diurnal variation, the electric current system responsible is external to the earth, and likewise gives rise to induced currents flowing within the earth. Its changes with magnetic activity, more marked than in the case of the solar diurnal variation, suggest that its current-system flows at another level in the atmosphere and possibly in the F region.

MAGNETIC STORMS

Magnetic storms (Fig. 14) are the most striking of all geomagnetic phenomena. These are characterized by large and complex changes in the field occurring on a world-wide basis. They are usually most marked in polar regions and are accompanied by unusual auroral displays, extending to somewhat lower levels than normal, and by earth-current disturbances. Associated with them are also marked ionospheric changes giving rise to widespread interruption of electrical communications. A singularly remarkable feature of the time variations of the storm field is that these are at times closely paralleled by variations in cosmic-ray intensity in low latitudes.

Aurora

The close relation between the aurora and the magnetic storm is held to be due to the fact that the former is the visible manifestation of streams of particles arriving from the sun and likewise causing the storm. The electrically charged particles are required by physical laws to spiral around the lines of force of the earth's magnetic field. The particles ionize the molecules by knocking out a negative electron and energizing the atoms so that they produce the visible radiation

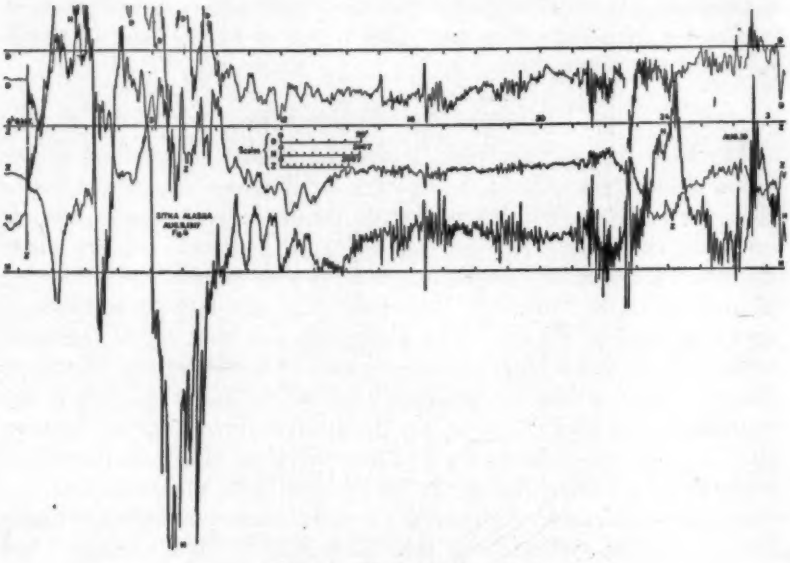


Fig. 14.—Magnetic storm.

seen in aurora. The usual penetration is to within about 110 km above the earth's surface, although this penetration varies with the type of the aurora. The observed upper limit is about 1,000 km in height. The most commonly observed forms of aurora are the homogeneous quiet arcs and the moving curtains or streamers, the latter types often with considerable coloration being especially related to magnetic disturbances.

Closed curves of equal auroral frequency, known as isochasms, drawn on maps of the polar regions show symmetry relative to the geomagnetic poles. The narrow belts forming the auroral zones, where aurora occur most frequently and with highest intensity, are

about 23° of latitude distant from the poles (Fig. 8). In this region also the magnetic changes of storms are particularly intense and highly differentiated locally.

Analysis of Storm Field

Chapman and others have shown that the surface field of storms may be analyzed into three main parts: (1) a part proceeding according to time measured from the commencement of storm, and known as the storm-time variation; (2) a diurnal variation additional to that also present on quiet days, but much greater in intensity and mark-

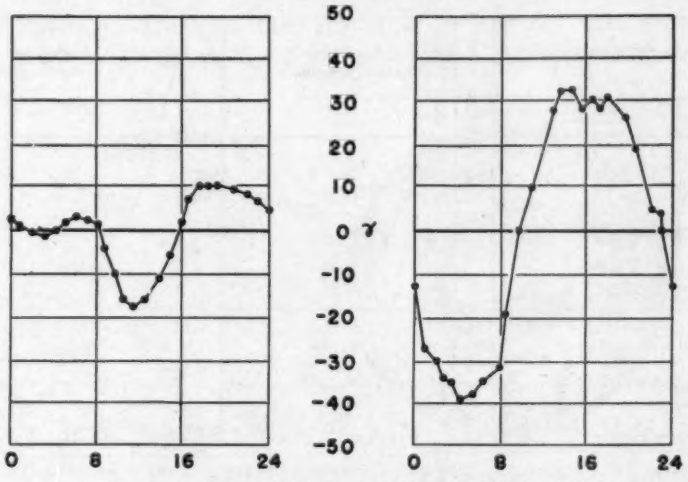


Fig. 15.—Quiet and disturbance daily variation in "H."

edly different in type, and known as the disturbance diurnal variation (Fig. 15); and (3) an irregular part, most marked in the polar regions, depending on latitude and in its average features on local time.

A large number of records of storms from many observatories have been analyzed. In low and middle latitudes the storm-time part of horizontal intensity (Fig. 16) rises to a maximum within 1 or 2 hours of the start, then there is a decrease to a value considerably below normal, the minimum being reached in 12 to 30 hours after the start. This is followed by gradual recovery till the normal value is reached. The greater the storm, the more rapid is the development of the phases.

Large storms often have sudden commencements, possibly coincident in time within a few seconds over the entire earth, though the

simultaneity has not been proved because of small time scales and uncertain time control.

The geographical distribution of the storm field is somewhat complicated, and it can best be treated by considering the several parts separately. The main characteristic of that part accounting for the storm-time portion is that the electric current flows east-west with greatest intensity near the auroral zone and at the equator. Fig. 17 gives part of the system according to Vestine and Chapman. For the part of the storm depending on local time the currents are very intense in the polar region. In fact, during a great magnetic storm the electric

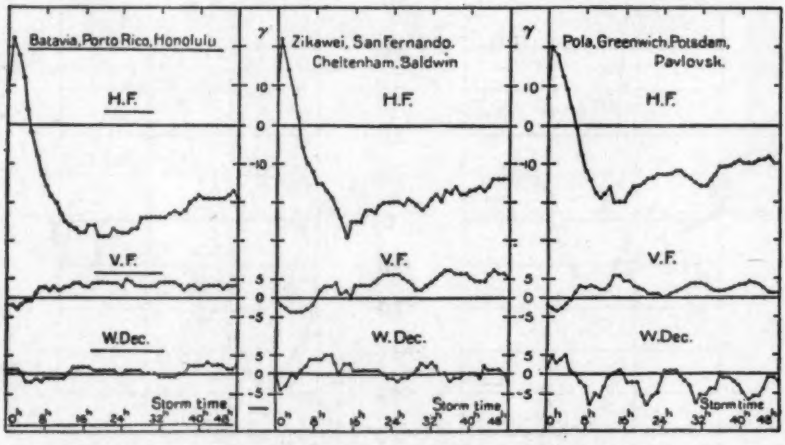


Fig. 16.—Storm-time magnetic disturbance changes in different latitudes.

currents flowing along the auroral zone may attain the intensity of about 1,000,000 amperes. It is probable that the height of the current systems is such that they are within the F layer.

However, a suggestion not warranted by the magnetic data alone and of doubtful probability seeks to account for the storm-time portion in middle and lower latitudes by a great equatorial ring current at a distance of several earth radii.

The current-systems indicated are undoubtedly too simple, and they have marked changes with time, but they provide a means of representation of the principal magnetic changes in the field during a magnetic storm. Intensive study of the changes in the storm field, and especially of the complete data on magnetic and other phenomena accumulated during the Second Polar Year, gives promise of important advances in the knowledge of the position and nature of the cur-

rents and of the origin of magnetic storms. The theory of magnetic storms is in a state of flux at the present time, and no completely successful theory has been proposed, though both corpuscular and ultraviolet theories have been advanced. According to Chapman and Ferraro a magnetic storm is caused by a neutral stream of charged particles which tend to separate in the earth's field, giving rise to the aurora and magnetic storms. The needed current-systems, including the intense currents observed in the auroral zone, may be provided in this way.

Special Forms of Magnetic Disturbance

Magnetic disturbances more moderate in intensity than those of storms frequently occur. Solar flares and associated magnetic effects

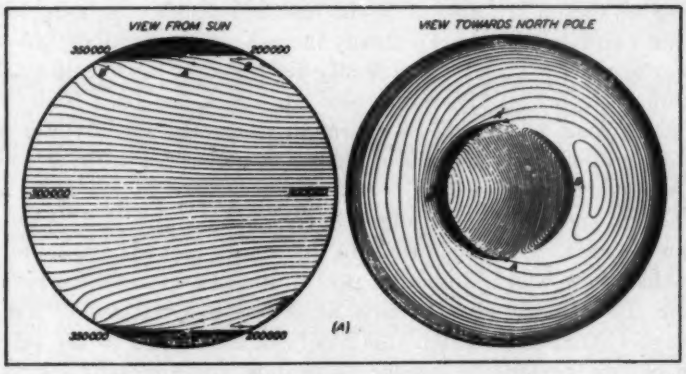


Fig. 17.—Part of current-system accounting for magnetic storms. (Courtesy Journ. Terr. Magn. and Atmos. Electr.)

have been discussed. In polar regions of the earth especially there are often simple, large intensifications (or diminutions) of the earth's field known as bays and lasting from 1 to 5 hours. These tend to occur on a world-wide scale and are more marked near the auroral zone. They may be regarded as due to some distorted and less intense form of the electric current-system of magnetic storms.

The earth's field also undergoes at rare intervals highly regular periodic changes known as pulsations. Micropulsations having periods of the order of seconds sometimes occur. These seldom extend over areas of greater extent than a few thousand square kilometers. Another interesting type is the giant pulsation having extremely regular sinusoidal variations with time of period of a few minutes. The causes of these pulsations are not known.

TERRESTRIAL MAGNETISM AND THE SUN

The average amount of magnetic disturbance is closely correlated with the average physical states of the sun associated with mean sun-spot numbers. The variation in the annual average of the amount of the magnetic disturbance on the earth is almost directly proportional to the variation in the mean sun-spot numbers taken for the corresponding year. The connection between individual magnetic storms on the earth and isolated or large sun-spots on the sun is somewhat indefinite, but it appears to be greater in the case of notable magnetic storms than in the case of moderate magnetic storms. Thus, magnetic storms tend to occur more frequently in years when there are many large sun-spots than in years when there are few.

At the beginning of a sun-spot cycle the sun's surface is free from sun-spots; then a few appear in the middle latitudes on both sides of the sun's equator. There is a steady increase in the number; the spots appear nearer the equator and finally disappear at the lowest attained latitudes. Record of the number of sun-spots has been maintained for many years at Zurich, Switzerland, where the final Wolfer numbers are prepared on the basis of reports from a world net of astronomical observatories.

The sun-spot cycle has ranged in the past from 8 to 17 years between maxima. From 1645 to 1715 the scanty records available indicate that there was a long quiet period, which appears to be reflected also in the tree-ring observations, according to Douglass, of the University of Arizona. Though this has been attributed to the interference of two periods of similar amplitude and different length, no periods have been found through analysis which would serve as a basis for accurate prediction. From 1878 to 1932 the average length of the cycle was 11.2 years with 4.6 years from minimum to maximum and 6.6 from maximum to minimum. There is great variation from cycle to cycle.

Most sun-spots occur in latitudes of the sun which have a mean rotation period of 27.3 days, and therefore a continuing disturbance on the sun's surface has approximately the same relation to the earth at this interval.

The natural inference is that if a corpuscular emission from the sun occurs it does so in the form of a stream or jet of electrified particles, this being inferred from the effect of the earth's magnetic field on the stream. Magnetic observations indicate that the jet is not necessarily normal to the sun's surface, since a storm has been observed two days before a spot reached the central meridian. The aver-

age arrival is 26 hours after the meridian passage of the spot, corresponding to a speed of 1,100 miles per second. There is a wide range in the time of arrival of the storm after the central meridian passage of the spot. This could be due to differences in the directions of jets on leaving the sun, and to the possibility that the place of emission from the sun is unknown.

Bauer, years ago, pointed out as a result of his analyses that sun-spot activity is not a whole measure of solar activity and that the photographic magnetic storm data and variations may intrinsically afford a better measure of solar activity. Bartels has expressed the view that there exist on the sun certain restricted regions, usually but not necessarily in the vicinity of sun-spots, the life of which is usually longer than that of the sun-spots but ordinarily not more than one year. These regions may emit corpuscular streams which cannot be detected by visual, photographic, or spectroheliographic means.

This conception of solar conditions helps to explain the numerous exceptions to normal occurrence, since sun-spots can occur without a magnetic disturbance and disturbances can occur on the earth without a sun-spot being visible. In the former case it is quite possible that a jet goes out but misses the earth. Sudden commencements indicate that the jets have sharply defined boundaries.

Accordingly it may be possible that certain solar problems may find solution through terrestrial magnetism. It may also be that effects of solar disturbance on magnetism and on the ionization of the ionosphere may together form an improved measure of solar activity.

RESUME

We have then the broad picture of an earth and an atmosphere in which the concentric shell is an outstanding feature (Fig. 4). Seismology shows us that the earth consists primarily of a core, a mantle, and a crust. The mantle is perhaps subdivided into several layers, but the surfaces of discontinuity between them are not yet fully defined. The most likely are on the order of 400 and 1,000 km below the surface.

The crust is a fairly definite conception, but its thickness depends to some extent on definition and on the geophysical method used in determining it. From seismology there appear to be several layers under the continents—layers much less in thickness under the Atlantic and Indian Oceans and nonexistent under the Pacific Ocean. Their depths from isostatic considerations have been discussed.

At least 94 percent of the earth's total surface-field magnetism is of internal origin. An accurate knowledge of this field is of great practical as well as theoretical value. The main field undergoes a secular variation. There are also periodic and aperiodic variations in the field appearing in superimposed form. These are caused by electric currents flowing above the ground and give rise to induced currents flowing within the earth. The space distributions of these currents cannot be inferred from magnetic measurements at the earth's surface, but additional nonmagnetic considerations result in determining them with a fair degree of probability. From these variations we deduce information about the earth's interior, the atmosphere, and the sun not forthcoming in any other way.

It is generally accepted that far ultraviolet light is the cause of the ionization which is responsible for diurnal variation, but that magnetic storms are probably associated with slower-traveling emanations from the sun. These are associated with sun-spots, but so indirectly that they appear to rise from disturbed areas on the sun which may or may not have sun-spots.

These are some of the things that have been accomplished, and all those who have taken part can feel pride in their share of the accomplishment. On the other hand, scarcely a start has been made on some of the principal problems. Explanations have not been reached for the magnetic field and its secular change or for the cause of magnetic storms. The immediate cause of deep focus earthquakes is not known, and the ultimate cause of all earthquakes is yet to be discovered, as well as many of the facts about the interior of the earth.

One of the needs is for data at many places, but new observatories should not be added until the interpretation of their records is provided for. One of the great problems in the world-wide studies is to obtain the needed observational data and yet not to do it in such a way as to restrict the interpretation of the results.

There is, therefore, ample challenge in both fields, and the complexity of the problems need not become a bar to progress if the advance is made on a sufficiently broad front and is maintained.

CHEMISTRY.—*The destruction of hydrocyanic acid by prunase and the influence of sugars on the reaction.*[1] JAMES F. COUCH and REINHOLD R. BRIESE, U. S. Bureau of Animal Industry.

In the course of investigations being conducted in this laboratory on cyanogenesis in plants, it has become evident that the cyanogenetic enzyme is one of the factors that cause loss of freed HCN. In 1889 Tammann[2] observed that, when dilute solutions of HCN were treated with emulsin, 5 to 50 percent of the HCN is no longer detectable after 24 hours. This observation seems to have been generally forgotten. It may, however, explain the fact reported by Auld[3] that when amygdalin and emulsin react the resulting solution contains less HCN than is equivalent to the dextrose formed during the reaction. In the analysis of cyanogenetic plants such a loss of HCN may be very serious, especially if the HCN content of the plant be small and the enzyme very active.

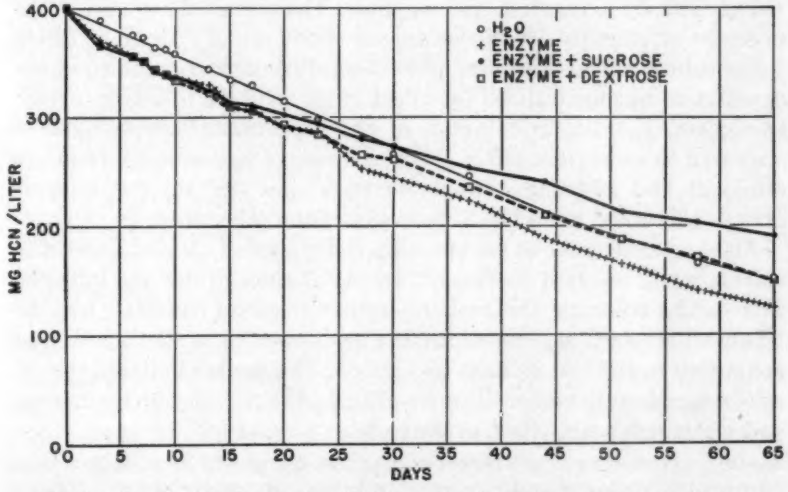


Fig. 1.—Graph of hydrocyanic-acid destruction in water and prunase solutions.

To obtain some quantitative data on this phenomenon a series of experiments was performed. Three liters of a water solution of HCN adjusted to contain 400 mg per liter were prepared. Four 750-cc portions were measured into 1-liter pyrex flasks. One portion was kept as a control. To the second portion was added 10 g of a crude

[1] Received February 21, 1939.
[2] Zeitschr. physik. Chem. 3: 25–37. 1889.
[3] Journ. Chem. Soc. T. 93: 1276–1281. 1908.

prunase preparation obtained from *Prunus serotina*. The preparation was made by extracting the cyanogenetic glucoside from fresh leaves with alcohol and drying the residue at room temperature. The powdered marc so obtained exhibited a strong activity toward crude prunasin. It gave 4.3 mg per 100 g HCN on analysis. The experimental results were corrected for the enzyme HCN.

Since there is some evidence that carbohydrates affect the rate of cyanogenesis in plants, a third portion was treated with 10 g of the enzyme preparation and 5 g of pure dextrose was added. A fourth portion was treated with 5 g of sucrose in addition to 10 g of the enzyme preparation. The four mixtures were stored in a dark place at $25° \pm 0.5°$ and 25-cc portions were withdrawn at intervals for analysis. The mixtures were well shaken several times a day. The results are plotted in Fig. 1. No attempt was made to adjust the mixtures to an optimum *p*H to avoid complication by possibly interfering substances. After 65 days the HCN content of the several lots was: 1, 151; 2, 129; 3, 155; and 4, 196 mg/liter. The curves show that in the presence of prunase HCN disappears more rapidly than in dilute water solution. Dextrose had little effect during the first third of the experiment but neutralized the effect of the prunase to a large extent thereafter. For the first fourth of the experiment sucrose likewise appeared to exert little effect. Then the rate of loss of HCN began to diminish and after the twenty-seventh day the sucrose mixture always contained more HCN than any of the other three.

Although the order of the reaction is not settled, it is of interest to calculate the reaction coefficient. In the absence of definite information to the contrary the monomolecular reaction constant was determined for each series and for the entire period of 65 days. These are stated in the last column of Table 1. The figures indicate the acceleration of the decomposition by prunase, the retardation by sucrose, and a negligible net effect of dextrose.

TABLE 1.—DESTRUCTION OF HYDROCYANIC ACID IN WATER AND PRUNASE SOLUTIONS

Solution	*p*H at end	HCN lost	*k*
		Percent	
Control	3.16	62.2	452×10^{-4}
Enzyme	4.10	67.7	523
Enzyme plus dextrose	3.80	61.2	445
Enzyme plus sucrose	3.82	51.0	320

It was thought that the retarding action of sucrose beginning only some 17 days after the start of the experiment might be due to inversion of the sucrose known to take place in aqueous solutions and

that the levulose as formed was actually the retarding compound. To test this hypothesis under actual plant conditions, dextrose, sucrose, and levulose were added to mixtures of ground fresh cyanogenetic plants with water and mercuric chloride as a preservative,[4] which were allowed to macerate for various times at 25°. At the end of four weeks to six months the stored mixtures were analyzed for HCN and compared with a control sample to which sugars had not been added. The latter, however, contained small amounts of their natural carbohydrates, dextrose in *Prunus serotina* and both dextrose and sucrose in the sorghums. The results appear in Table 2. There

TABLE 2.—EFFECT OF SUGAR ADDED TO CYANOGENETIC PLANT MIXTURES

Date	Plant	Weight of plant	Weight of sugar added	$HgCl_2$	Period	HCN recovered after adding—			
						Dextrose	Sucrose	Levulose	Control
1938		*g*	*g*	*Per cent*	*Weeks*	*mg/100 g*[1]	*mg/100 g*[1]	*mg/100 g*[1]	*mg/100 g*[1]
May 22	Prunus serotina	25	5	2	26	101	100		102
May 22	Prunus serotina	25	5	2	4	98	94		99
June 28	Prunus serotina	25	5	2	4		129		129
July 18	Sorghum vulgare var. hegari	50	2.5	2	8	38	38	40	39
July 25	Sorghum vulgare var. hegari	50	2.5	2	8			35	37
July 27	Sorghum vulgare var. Sharon kafir	50	5	2	8			14	14
July 28	Sorghum vulgare var. hegari	50	5	2	8			28	28
Aug. 22	Sorghum vulgare var. hegari	50	5	3	4	30	33	36	34

[1] mg per 100 g of plant.

are no very significant differences between the figures for the various sugars and the controls. Levulose appeared to yield slightly higher results than dextrose or sucrose but did not differ significantly from the controls. The differences observed between these experiments and those reported in Table 1 may be ascribed to the presence of mercuric chloride which combines with the HCN liberated by enzymolysis of the glucoside and indicate that any direct action that carbohydrates may exert in cyanogenetic mixtures is on the freed HCN rather than on the enzymolysis. In the absence of a preservative like mercuric chloride, prunase is capable of accelerating the decomposition of HCN in water solution. Dextrose and sucrose neutralize this action but only after some time has elapsed.

[4] Briese, R. R., and Couch, J. F. Journ. Agr. Res. 57: 81–107. 1938.

BOTANY.—*New species of* Taphrina *on red maple and on silver maple.*[1]

ANNA E. JENKINS, U. S. Bureau of Plant Industry.

As a result of an investigation of two species of *Taphrina* occurring on North American maples, one on *Acer rubrum* L. and the other on *A. saccharinum* L., the taxonomic history of these two fungi may now be assembled.

THE SPECIES OF TAPHRINA ON RED MAPLE

The species of *Taphrina* on red maple is considered to be new and is named in honor of Prof. John Dearness, whose collections of the fungus in Ontario, Canada (1890–98), are basic to the study. The several specimens gathered in 1898 indicate that the fungus was abundant and destructive in that year (Fig. 1, A and B). His earliest specimen (Dearness 1730), of June 1890, is represented by Ellis and Everhart's Fungi Columbiani 1272 and by North American Fungi 2596, second series. In the order named, these exemplify the two separate descriptions of *Ramularia lethalis* E. & E. (2, 3), as Dearness has explained in letters to the writer. The printed label for North American Fungi 2596, however, bears the date October 1890. Finding the asci in good condition on this specimen bearing an autumn date, the writer brought this to the attention of Dearness; he stated that "October" was erroneous; for the entire gathering was definitely made in June. The *Taphrina* on this material has not hitherto been identified, and the *Ramularia* is regarded as an associated and presumably distinct species, such as the undetermined imperfect that has been observed by the writer on other specimens of this *Taphrina*.

Through the kindness of Professor Bessey, it was possible to examine from the Herbarium of the Michigan State Agricultural College a similar specimen bearing the label:

Ex herb. Agricultural College, Mich.
49 *Gloeosporium aceris* Cooke
On *Acer rubrum*
N. of College 1890

The name "*Gloeosporium aceris* Cooke" (1) is here in the handwriting

[1] This account is part of a paper read December 30, 1938, before the Joint Session of the Mycological Society of America and the American Phytopathological Society at the 103d meeting of the A.A.A.S., Richmond, Va. During July and August 1938, the writer was a guest worker at the Department of Botany, University of Wisconsin, and studied many of the specimens herein discussed. Grateful appreciation is expressed to the chairman of this department, Prof. E. M. Gilbert, for privileges and courtesies extended; to Drs. H. D. House, D. H. Linder, I. E. Melhus, and F. J. Seaver for permission to study material in their charge; and to Profs. E. A. Bessey, G. W. Carver, J. Dearness, E. B. Mains, H. M. Fitzpatrick, and others for correspondence, contribution of specimens, and access to certain other specimens. Received February 24, 1939.

of Beal, according to Bessey. On the large discolorations of the leaves of this species the writer found a species of *Taphrina* identical with that which Dearness collected in Ontario the same year.

Other early gatherings of this species of *Taphrina* also available are as follows: Alabama, Notasulga and Tuskegee, Apr. 29, 1897, G. W. Carver 154; Michigan, near Lansing, June 2, 1897, C. F. Wheeler; North Carolina, May 1901, comm. F. Sherman, Jr. Under his generic determination of "*Exoascus?*" Carver sent part of the first specimen just cited to Ellis, who labeled it doubtfully *Gloeosporium decolorans* E. & E., a species previously described (4) on red-maple leaves from Ontario collected by Dearness. The Wheeler specimen from Michigan, referred to immediately above, consists of about 25 well-preserved leaves on which the dark discolorations, often along the main veins, contrast strongly with the remaining green areas (Fig. 1, C). This specimen, heretofore unidentified, has remained practically lost, the only available label being what is evidently Wheeler's field label, giving only locality ("Woods S. of C. and G. T. R. R." = Southeast of Lansing), date, and his initials as collector (Fig. 2, A). The handwriting on this label and also on that shown in Fig. 2, B, referred to later, has been verified by Prof. Bessey as almost certainly Wheeler's, except for the initials on the second label, which he states are not written in the usual manner shown in Fig. 2, B. It is of particular interest that the third specimen mentioned above was sent by the North Carolina State Commission for Controlling Crop Pests to the U. S. Department of Agriculture for identification of the fungus causing a severe leaf disease (Fig. 1, D, E). The fungus was studied by Mrs. Flora W. Patterson as a possible species of *Taphrina*, although her records indicate that she found no asci.

In 1923, the writer collected a fresh specimen of a destructive fungus on red-maple leaves at Walton, Delaware County, N. Y., and identified it as belonging to the genus *Taphrina*. This specimen, together with that from North Carolina, was subsequently reported by the writer (5) as a new species of this genus, but without diagnosis or name. Later gatherings of the fungus in New York and Pennsylvania have been made (Fig. 3, A–G), and these will be cited following the technical description.

In size the asci of this species (Fig. 4, A) are much smaller than those of *T. lethifera* (Pk.) Sacc. on mountain maple (*Acer spicatum* Lam.) illustrated elsewhere (6, Fig. 2, A). As compared with the asci

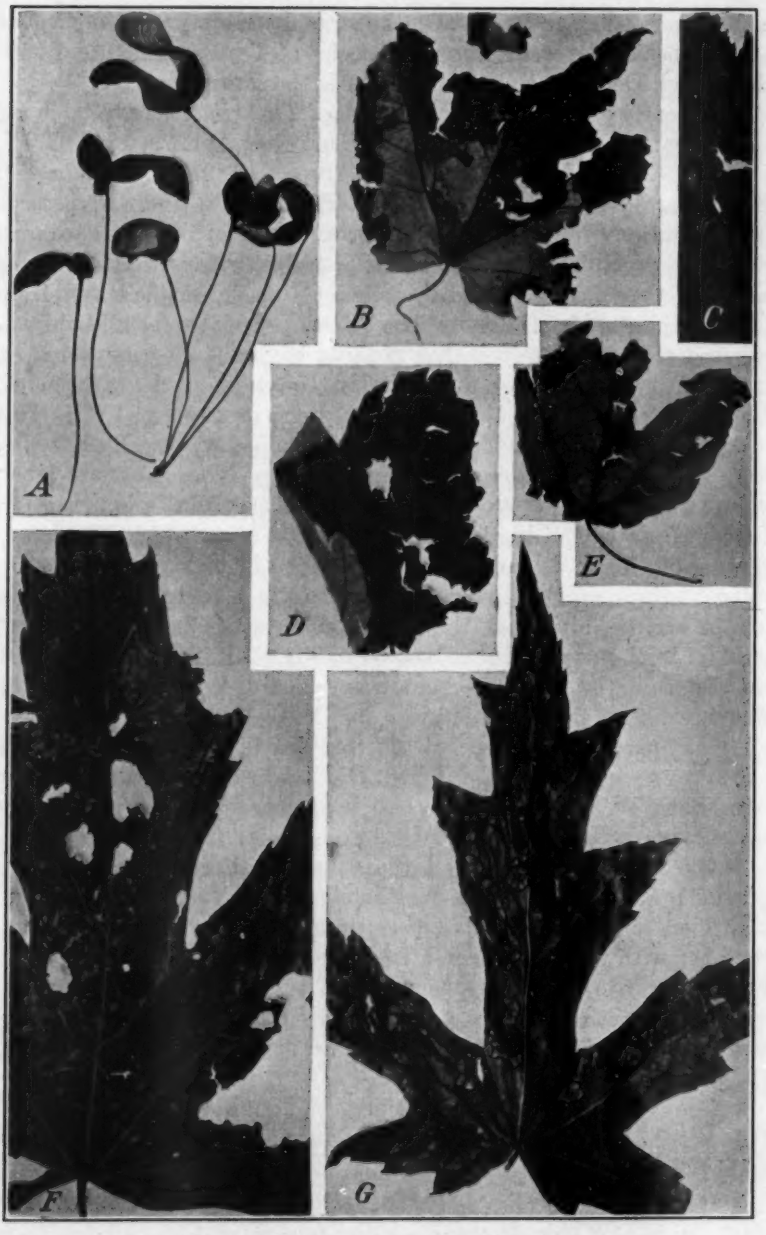


Fig. 1.—*(See opposite page for explanation.)*

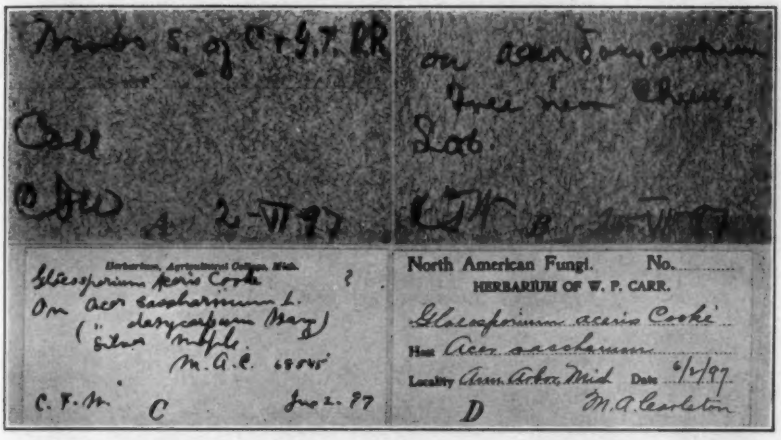


Fig. 2.—A and B: Wheeler's original labels accompanying specimens of diseased red (A) and silver (B) maple leaves he gathered on June 2, 1897. C: In Beal's handwriting, herbarium label for the silver-maple leaves; herbarium number 68545 (Myc. Coll. B.P.I.) added by the present writer. D: Label for the leaves of this specimen from the Carr Herbarium. Photographs of original labels by Eugene Herrling.

of *T. sacchari* Jenkins (Fig. 4, C[2]), recently described (7) on sugar maple (*A. saccharum* Marsh.) the asci of the red-maple species are generally the larger. The form of the asci of these three species may be compared in the illustrations cited.

This species, designated as *Taphrina dearnessii*, is described as follows:

Taphrina dearnessii n. sp.

Spots located anywhere on the leaf, although often marginal or scattered along the main veins and more or less delimited by them, sometimes causing a wrinkling of young leaves, more or less circular or angular, of various sizes, deciduous, discolorations sometimes covering entire area between main veins or involving practically entire leaf, on dry specimens often "bister" (9) to "blackish brown"; at center sometimes "cinnamon" and somewhat translucent; affected samarae discolored entirely or in part; asci numerous, covering discolored areas on samarae or hypophyllous, rarely epiphyllous,

[2] In a previous article (8) a citation was made to an unpublished paper ("A Species of *Taphrina* on Red Maple") containing an illustration (photomicrograph of asci and ascospores) of *Taphrina sacchari*. In the present paper, containing part of the data in the unpublished article, Fig. 4, C is adapted from the unpublished photomicrograph.

Fig. 1.—A–E: *Taphrina dearnessii* on samarae (A) and leaves of red maple (B–E) from (A) London, Ontario, June 1898, J. Dearness (E. and E. Fungi Columbiani 1348); (B) McGillivray, May 31, 1898, J. Dearness; (C) vicinity of Lansing, Mich., June 2, 1897, C. F. Wheeler; (D and E) North Carolina, 1901. F and G: *T. carveri* on silver-maple leaves from (F) Lansing, Mich., June 2, 1897, C. F. Wheeler, and from (G) Tuskegee, Ala., Apr. 30, 1897, G. W. Carver. B and D, lower leaf surface, others upper leaf surface. All ×1. Photographs by Eugene Herrling (A and C) and M. L. F. Foubert (B and D–G).

Fig. 3.—*Taphrina dearnessii* on red-maple leaves from (A) La Porte, Pa., 1933, L. O. Overholts; (B–F) Walton, N. Y., June 16, 1929, A. E. Jenkins, type; and (G) Lewis Co., N. Y., 1927, D. S. Welch and C. H. Cunningham; A and C, upper leaf surface, others lower surface. E, *a*, light or cinnamon color of lesion. All × 1. Photograph by Eugene Herrling.

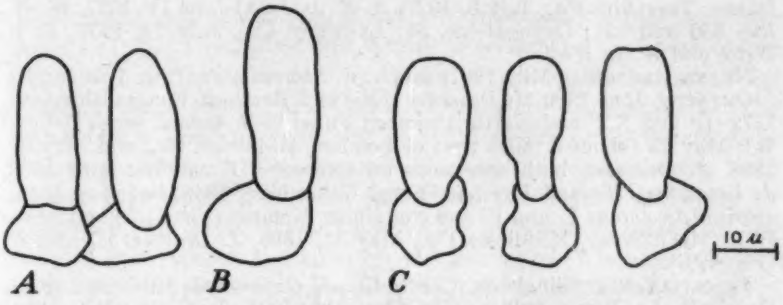


Fig. 4.—A: Asci of *Taphrina dearnessii* from type specimen, represented in Fig. 2, B–F. B: Ascus of *T. carveri* from type specimen, represented in Fig. 1, F. C: Asci of *T. sacchari* from specimens from Wisconsin, June 1904, illustrated elsewhere (8).

cylindrical to slightly clavate, at apex rounded or truncate 17–29μ high by 8–13μ wide, often 21–29μ by 10–11μ, sometimes sunken in the stalk cell as much as 3.5μ, containing 8 spores at first; stalk cell rounded, flattened or slightly pointed at base, rarely moderately lobed, resting on the epidermis, 6–12μ high by 10–18μ wide; spores globose to elliptical, 2.8–5.6μ by 3–3.5μ, budding in the ascus.

Maculas circulas vel angulares efficiens; asci hypophylli, raro epiphylli, cylindrici usque clavati 17–29μ × 8–13μ plerumque 21–29μ × 10–11μ; cellulae basilares 6–12μ × 10–18μ; subglobosa vel elliptica, sporidia 2.8–5.6μ × 2.8–3.5μ.

Distribution and specimens examined.—On *Acer rubrum* L., causing "leaf blister of red maple."

ALABAMA: Notasulga (about 12 miles from Tuskegee) [NY and W][3] and Tuskegee [C–IS and W], Macon Co., Apr. 29, 1897, *G. W. Carver* 154.

MICHIGAN: North of College, Lansing, Ingham Co., 1890 (Ex Herbarium Michigan State Agricultural College 49) [MS]; southeast of Lansing, June 2, 1897, *C. F. Wheeler* [MS and W] (Fig. 1, C).

NEW YORK: Walton (Mountain Home Farm), Delaware Co., Aug. 1, 1923, *A. E. Jenkins;* July 10, 1924, *F. A. Jenkins;* July 20, 1924, *A. E. Jenkins;* June 20, 1925, *E. J. Hoose;* July 22, 1927, and June 16, Type 69297 [W][4] (Fig. 3, B–F), and June 17, 1929; Lewis Co., Fisher Tract, Number 4, June 21, 1927, *D. S. Welch* and *G. H. Cunningham* (Fig. 3, G); vicinity of

[3] In this paper herbaria in which are filed specimens examined during this study are indicated as follows:

C–IS Carver Collection, Herbarium of the Iowa State College, Ames, Iowa.
D Dearness Herbarium, London, Ontario.
F Farlow Cryptogamic Herbarium, Harvard University, Cambridge, Mass.
MS Herbarium of the Michigan State Agricultural College, Lansing, Mich.
NY New York Botanical Garden.
P Peck Herbarium, N. Y. State Museum, Albany, N. Y.
UW Herbarium of the University of Wisconsin, Madison, Wis.
W Mycological Collections of the U. S. Bureau of Plant Industry, Washington, D. C.

Where no symbol is given the specimen is in the Mycological Collections; the symbol "W" is only employed when the specimen cited also exists in another herbarium.

[4] The specimens designated as types are chosen because they are thoroughly representative of the species, although neither was gathered by the person in whose honor it is named.

Ithaca, Tompkins Co., July 9, 1927, *A. E. Jenkins;* June 11, 1937, *W. W. Ray* 350 and 351; Oswegatchie, St. Lawrence Co., July 12, 1937, *D. S. Welch* and *W. L. White.*

NORTH CAROLINA: May 1901, comm. *F. Sherman, Jr.* (Fig. 1, D and E).

ONTARIO: June 1890, *J. Dearness* (Ellis and Everhart Fungi Columbiani 1272 [D[5] and NY] and North American Fungi 2596, second series [D[5] and W]; May 23 (about 8 miles west of London, Middlesex Co., and May 24, 1898, *J. Dearness,* both specimens on samarae [D and W]; June 1898, *J. Dearness* (Ellis and Everhart Fungi Columbiani 1348, issued as *Gloeosporium decolorans* E. and E. and containing samarae (Fig. 1, A) and leaves [W]); McGillivray, Middlesex Co., May 31, 1898, *J. Dearness* [D and W] (Fig. 1, B).

PENNSYLVANIA: Shingleton, Centre Co., *L. O. Overholts* 18149 and *W. A. Campbell,* La Porte, Sullivan Co., June 14, 1935, *L. O. Overholts* 18148 (Fig. 2, A).

THE SPECIES OF TAPHRINA ON SILVER MAPLE

A species of *Taphrina* on silver maple (*Acer saccharinum*) (often called white maple) was collected in Ontario, at Lucan, by Dearness (Dearness 2144) on July 17, 1893. He sent a specimen to Prof. C. H. Peck, at Albany, N. Y., where it was first seen by the writer in 1931. Peck labeled the specimen "*Gloeosporium maculosum,*" but a description was never published. From the fact that Peck intended to describe the fungus as a *Gloeosporium* it is clear that he did not realize that a species of *Taphrina* was concerned.

Four years after Dearness collected this species in Canada on April 30, 1897, Carver collected it on severely diseased leaves of silver maple at the Tuskegee Institute (Fig. 1, G). Having discovered the *Taphrina,* he sent a specimen (Carver 153) bearing his generic determination to Ellis, but there is no indication that Ellis ever studied it, and Carver has recently written that he finds no mention of it in Ellis's correspondence with him. Dr. Carver has also written (Feb. 20, 1939) that the young trees from which he collected this species of *Taphrina* were said to have been sent from a nursery in Iowa.

On June 2, 1897, Wheeler also made an ample collection of diseased leaves from a tree of silver maple growing on the campus of the College at Lansing, Mich. (Fig. 1, F). Unfortunately, until the present, this specimen has been labeled "*Gloeosporium aceris* Cooke?" The herbarium label is in the handwriting of Beal (Fig. 2, B), although Wheeler's original label, "On *Acer dasycarpum,* tree near Chem. Lab., C.F.W. 2-VI-97" (Fig. 2, C), is at hand. Years later, after studying this specimen, the writer (5) reported it as a new species of *Taphrina,* although without name or description. The specimen

[5] The specimen in the Dearness Herbarium is here part of the original gathering retained by Dearness and not issued as a part of this exsiccatum.

studied at that time was unfiled in the Mycological Collections of the Bureau of Plant Industry, but it was later learned that part of the gathering with the same label by Beal is also in the Herbarium of the Michigan State Agricultural College. During the summer of 1938 the writer found in the Herbarium of the University of Wisconsin a packet containing a few diseased silver-maple leaves, which were subsequently traced as having come from the original gathering by Wheeler in the Mycological Collections. Although prepared on the basis of Beal's label, the label on the packet at Wisconsin showed certain misinterpretations. For the "M.A.C." of Beal's label, signifying the "Michigan Agricultural College" at Lansing, was here substituted for the actual collector as "M. A. Carleton," and "Ann Arbor" was introduced as the place of collection. Nevertheless, upon finding this specimen labeled as illustrated, the writer was convinced from the first that it was part of Wheeler's gathering.

Since Carver appears to have been the first to observe the asci of this species of *Taphrina* (Fig. 4, B), it seems particularly fitting that it be named in his honor. It is therefore named *T. carveri*, and is described as follows:

Taphrina carveri n. sp.

Discolored areas on leaves sometimes somewhat wrinkled, scattered or occasionally confined to one part of the blade, consisting of circular, elliptical or irregular spots up to 25 or more on a single leaf and up to 3 by 1 cm in diameter, or of more elongated areas situated between the main veins and reaching the leaf margins, on dry herbarium specimens "sepia" above, "isabella color" and "light brownish olive" below, to "blackish brown" on both surfaces, sometimes upper surface covered with delicate bloom; asci amphigenous, more commonly hypophyllous, usually cylindrical, at apex rounded or truncate, 23–35μ high by 7.8–16.8μ wide, often 26–30μ by 9–15μ, with spores (apparently 8 at first) and many budded conidia; stalk cell rounded, flattened or irregular, sometimes slightly pointed at base, occasionally moderately lobed, resting on the epidermis, 4–15μ high by 10–22μ wide; spores subglobose or elliptical 4–7μ in diameter; budded conidia variable, spherical to oblong-elliptical, latter reaching 7 by 3μ.

Maculas circulares, ellipticas vel irregulares, usque 3 cm diam. efficiens; asci amphigeni, saepius hypophylli, plerumque cylindrici, 23–35×7.8–16.8μ; cellulae basilares 4–15μ×10–22μ; sporae subglobosae vel ellipticae, 4–7μ in diam.; conidia variabilia, spherica usque oblongo-elliptica, usque 7×3μ.

Distribution and specimens examined.—On *Acer saccharinum* L., causing "leaf blister of silver maple."

ONTARIO: Lucan, July 17, 1893, *J. Dearness* 2144 [D, P, and W].

ALABAMA: Tuskegee, Macon Co., Apr. 30, 1897, *G. W. Carver* 153 [F, C–IS, and W] (Fig. 1, G).

MICHIGAN: Lansing, Ingham Co., June 2, 1897, *C. F. Wheeler* [MS, W, and UW], Type 68545 [W][4]. (Fig. 1, F).

LITERATURE CITED

1. Cooke, M. C. *New American fungi.* Grevillea **12**: 22–33. 1883–1884.
2. Ellis, J. B., and Everhart, B. M. *New species of fungi from various localities.* Proc. Acad. Nat. Sci. Philadelphia, 1891, pp. 76–93. 1892.
3. —— *New species of North American fungi from various localities.* Proc. Acad. Nat. Sci. Philadelphia, 1893, pp. 128–172. 1894.
4. —— *New species of fungi.* Journ. Myc. **7**: 130–135. 1894.
5. Jenkins, A. E. *Leafspot and blight caused by* Taphrina *spp.* Bur. Plant Ind. Plant Dis. Rpt. Suppl. **37**: 371–373. 1925.
6. —— *Emendations to the descriptions of* Taphrina lethifera *and* T. aceris *on maple* (Acer). Journ. Washington Acad. Sci. **28**: 350–353. 1938.
7. —— *A new species of* Taphrina *on sugar maple and black maple.* Journ. Washington Acad. Sci. **28**: 353–358. 1938.
8. —— *An early occurrence of* Taphrina sacchari *in Wisconsin.* Mycologia **30**: 689–691. 1938.
9. Ridgway, R. *Color standards and color nomenclature.* 32 pp., Washington, D. C. 1912.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

BOTANICAL SOCIETY

286TH MEETING

The 286th regular meeting was held in the assembly hall of the Cosmos Club, January 4, 1938, President G. F. Gravatt presiding; attendance 88. Albina F. Musil, Harriet Cull, and C. Eugene Larsen were elected to membership.

Notes and Reviews.—C. R. Ball called attention to a new book, *Botanical studies of the Uinta Basin of Utah and Colorado,* by Edward H. Graham, published in the Annals of the Carnegie Museum.

Program.—Reports of the papers presented at the meeting of the American Association for the Advancement of Science at Indianapolis, Ind., were given by: A. G. Johnson on pathology; E. E. Clayton on tobacco diseases; E. C. Johnston on physiology; Howard Johnson on forage crop diseases; Eubanks Carsner on entomology; George M. Darrow on small fruits diseases; J. B. Demaree on fruit and vegetable diseases.

287TH MEETING

The 287th meeting was held in the assembly hall of the Cosmos Club, February 1, 1938, President Gravatt presiding; attendance 125. Vernon T. Stoutmeyer, E. A. Hollowell, H. C. Hyland, Richard P. White, and F. D. Fromme were elected to membership.

Program.—F. D. Richey: *Collecting corn ornaments.*

A. C. Foster: *The effect of environment on the metabolism and blossom-end rot disease in tomato.* Extensive data were collected from 8 crops of tomatoes grown under controlled greenhouse conditions involving differences in soil moisture, soil nutrition, air temperature, light duration, and the interrelation and interaction of these component factors, any one of which may become a limiting factor to normal plant growth, and metabolic and respiratory activity, and thereby interfere with the normal development of tomato fruit.

The data suggest that the factors affecting the development of blossom-end rot are far more complex than is usually recognized: (1) High carbohydrate plants had the largest percent of the disease when grown under short day period; (2) high nitrogen plants were very susceptible to the disease

under long day conditions; (3) soil moisture at 70 percent of saturation was optimum for vegetative growth and also optimum for the disease; (4) superphosphate had a marked effect in reducing the incidence of the disease; (5) the rate of transpiration or water requirement apparently had no relation to the disease as it appeared under both extremes when other conditions were favorable; (6) one component factor of the environmental complex may become a limiting factor to the normal activity of all others and promote conditions favorable to causing the disease.

288TH MEETING

The 288th regular meeting was held in the assembly hall of the Cosmos Club, March 1, 1938, President GRAVATT presiding; attendance 110. C. W. EMMONS was elected to membership.

Notes and Reviews.—GEORGE DARROW called attention to the following articles: *Physiological genetics*, by Robert Goldsmith, Journal of Heredity, vol. 20, 1938; *Physiologic curve of response by seeds, growing plants, cuttings and lower plant forms*, by N. H. Grace, National Canadian Research Journal, Nov. 1937; *Aneurin and the rooting of cuttings*, by Went, Bonner and Warner, Science, Feb. 18, 1938.

Program.—W. A. ARCHER: *Plant exploration in Latin America.* It was pointed out that the chief disadvantages of travel in tropical countries were the monotonous diet and the numerous insect pests, especially those that transmit infectious diseases. The more striking of the plant finds were some giant peanuts from the Matto Grosso as well as the tiny seed of the wild peanut. Of interest also was the recovery of some long-lost tobacco strains in Costa Rica from volunteer plants that had sprung up from seed lying dormant for a generation under the floors of houses. In that country often when an old house is demolished by the owner or by earthquake the tobacco seeds germinate and produce plants.

IRVING T. HAIG: *Silvicultural history of the western white-pine type.* The creation of the United States Forest Service in 1905 marked the first formal step toward the practice of silviculture over extensive land areas in the Western States. The formulation of satisfactory methods of cutting in the complex and variable forests characterizing the western white-pine type in the Northern Rocky Mountain region was obviously a task of considerable difficulty, particularly as at that time little or nothing was known about the silvical habits or requirements of the associated tree species other than their names, botanical description, and general occurrence.

As a result of research, plus accumulated experience, the system of cutting on national forests, starting out with a scattered seed-tree system, swung through a complete cycle and back to this same system in about one decade, some five other systems of cutting having been employed. Present trends, mainly influenced by economic conditions, are toward a crude two-cut shelterwood system.

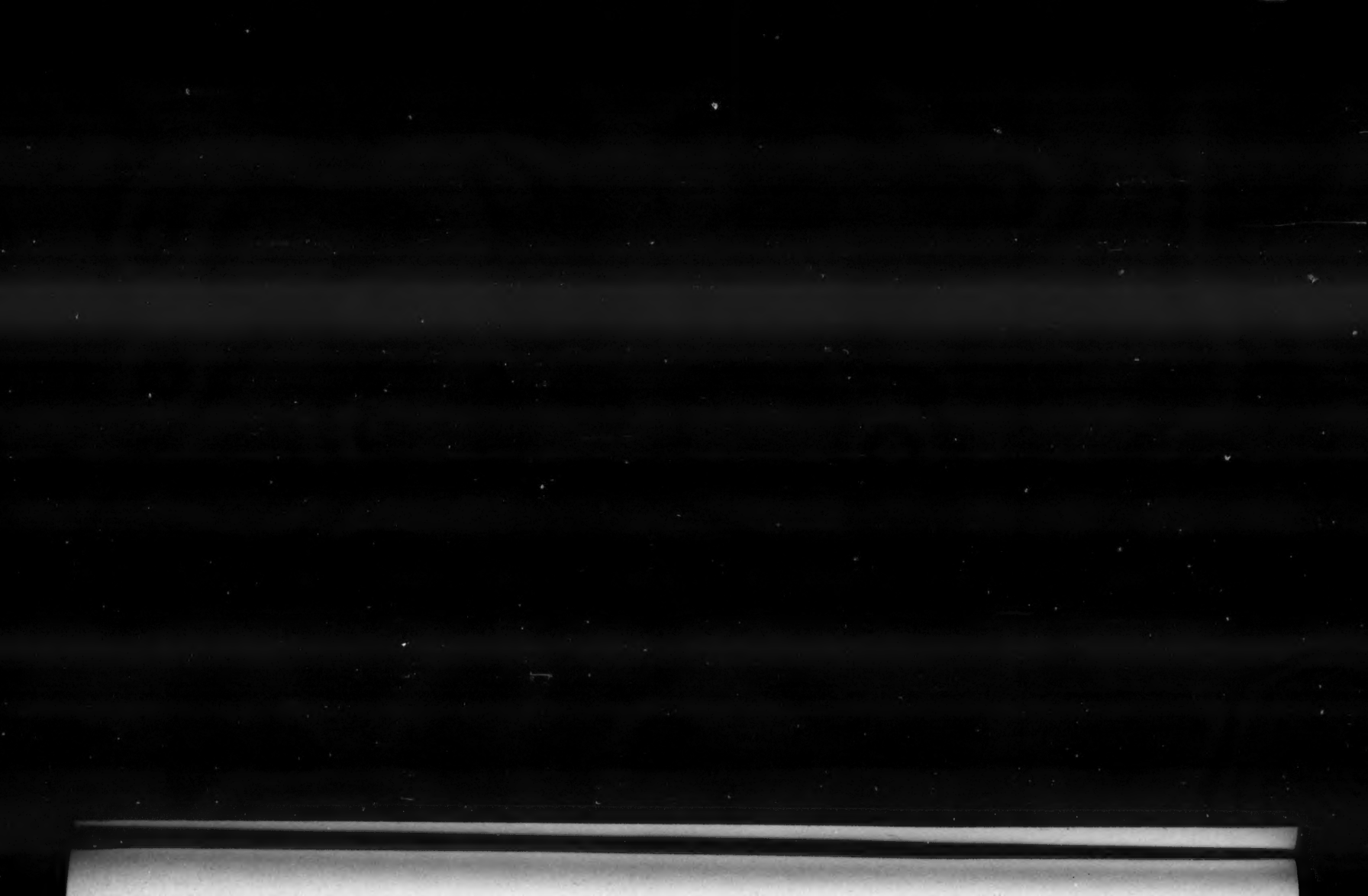
289TH MEETING

The annual banquet and 289th regular meeting was held in the ballroom of the Kennedy-Warren Hotel, April 5, 1938; attendance 80. Professor Whetzel of Cornell University was a guest of honor at the dinner.

Program.—WALTER C. LOWDERMILK gave an illustrated lecture on *Soil conservation and the California floods.*

SPECIAL MEETING

A special meeting was held in the auditorium of the U. S. Department of

Agriculture, April 19, 1938, at which PHILIP R. WHITE of the Rockefeller Institute spoke on *Root cultures and root pressure.* The history of theory concerning the mechanism of sap movement, a subject of investigation and controversy for the past 350 years, was briefly outlined. The "cohesion theory" of Dixon and Joly and of Askenazy has in the past 30 years largely superseded all others. This theory, however, possesses certain weaknesses and is incapable of explaining water movement under conditions of saturated atmosphere, as in the rain forests of the tropics.

Experiments with growing excised tomato roots have shown that such roots regularly maintain a continuous, rhythmic, basipetal flow of water in quantity and under pressures adequate to satisfy the needs of the tallest trees under conditions unsuitable for the functioning of the cohesion scheme. Secretion pressures of at least 6 atm. were recorded. This process is dependent on the activity of living cells. The two processes—secretion flow and transpiration flow—supplement one another and together seem capable of providing a complete and adequate explanation of sap movement. ALICE M. ANDERSEN, *Secretary.*